THE PATHOLOGY

OF

DENTAL CARIES.

BY

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[*From the* "TRANSACTIONS" OF
THE ODONTOLOGICAL SOCIETY OF GREAT BRITAIN.]

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GENERAL MONTHLY MEETING.

Monday February 1, 1864.

EDWIN SAUNDERS, Esq., President, in the Chair.

The following Gentlemen were duly elected Members of the Society:—

Mr. Charles Gibbs Nightingale ... Shrewsbury.
Mr. Thos. White .... Upper Eccleston Place.

The following Gentlemen were proposed for the Membership of the Society:—

Mr. F. Petty.
Mr. E. Moore.

Mr. Carl Tellander, of Stockholm, was recommended for corresponding Membership.

The following Contributions were made to the Society:—

By S. N. Dentz, Esq., Amsterdam, "Traité Pathologique et Thérapeutique des principales Affections de la Cavité Buccale, par S. N. Dentz."

S. L. Rymer, Esq., model showing two united lower incisors.

J. R. Mummery, Esq., models showing retarded development.

James Bate, Esq., model of supernumerary tooth.

H. L. Spencer, Esq., model showing a space of five-sixteenths of an inch between lower central incisors, the temporary teeth having been close together.

Edwin Saunders, Esq., models showing irregularity of upper incisors.

W. G. Bennett, Esq., model showing the presence of temporary canine at the age of fifty-four years.

G. Ash, Esq., a section of hippopotamus tooth, showing a cavity lined with enamel.

The SECRETARY read the following Paper on the "Pathology of Dental Caries," by C. SPENCE BATE, Esq., F.R.S. :—

PATHOLOGY OF DENTAL CARIES.

"Pathology aims at ascertaining the causes which determine every departure from the natural type, whether of form or function."

BUCKLE'S "CIVILIZATION IN ENGLAND."

1. *Introduction.*—It must be a self-evident proposition that, in order to arrive at the pathological history of any organ, we should first be well acquainted with its normal condition as it exists under the most favourable circumstances. Previously to entering upon any investigation of the subject of this paper, I have endeavoured to ascertain the character of the most healthy and perfectly developed structures that I have been able to obtain, in order to compare them with those which are under the influence of disease.

2. *Teeth of Wild Races.*—With this view I made sections of the teeth of the Flat-headed Indian and Esquimaux. Wild races, while they inhabit every region of the earth, and are subject to the most varied influences in both food and climate, are stated by travellers uniformly to possess teeth in a healthy condition, and free from caries, a disease that is so very common in civilized life. Having examined the microscopical appearances of these, and compared them with the most perfectly developed teeth of the European, and com-

paratively tested them by examinations with the teeth in the highest races of animals below man, I think that the following conclusions relative to the normal character of healthy developed tissues may be confidently accepted.

3. *Character of Normal Enamel.*—The enamel as a whole is a semi-transparent tissue, being everywhere uniformly of the same consistency, the wavy columns lying so closely in contact with each other as only to be distinguishable under the influence of a strong light and a highly magnifying power. This close connection of one column with its neighbours is equally persistent in the relations of enamel with the dentine. The structure of the tissue approximates a homogeneous condition, and wraps the dentine in a covering that is impervious to the most subtile fluids, and is capable of resisting, in its healthy state, all but the most destructive chemical agents.

4. *Character of Normal Dentine.*—The dentine, under the most favourable conditions, is much more opaque than the enamel, and this opacity decidedly increases as it progresses from the periphery to the centre of the tooth. A thin section, viewed by the assistance of transmitted light, shows that the structure is most transparent at the circumference, and that this is due to the thinning of the dentinal tubes, and their distribution in a field of larger area, whereas nearer to the pulp cavity the area is constricted, and the

diameter of the tubuli greater. I think that we may accept that, as a law, the tubuli anastomose with one another, and that their termination in free extremities is exceptional, as also is the circumstance of their penetrating into the structure of the enamel.

5. The more completely that these appearances are found to exist in a tooth, the more perfect is the development of the organ, and the less is it liable to succumb to the influences of deteriorating agents. But, on the other hand, any departure from these favourable conditions must be at the expense of the equilibrium between the organic and inorganic bases; a circumstance that must depauperize the structure, and leave it now within the influence of merely chemical laws. Although the healthy normal condition of enamel is a compact and semi-transparent uniform structure, yet these conditions are seldom met with in those teeth which commonly fall under our observation. This probably arises from the circumstance that the teeth which are generally obtained in practice are in a more or less diseased state. I therefore think that we may justly assume that the altered conditions of the structure are dependent upon its abnormal development, and are precisely such as admit of disease.

6. *Imperfectly Developed Enamel.*—If we examine the general appearance of teeth, we shall frequently observe a series of depressed lines,

some very minute, whereas others are more deeply marked, traversing the surface of the enamel in a horizontal direction in tolerably regular succession. This is so constant a feature, that the manufacturers of artificial substitutes frequently make it an object of special imitation. If we make a section of one of these "ribbed" teeth in a direction vertical to these little grooves, it will be found that each depression is constant with an opaque line that traverses the tissue subparallely with the external surface. Those which were first developed lie deepest in the tissue, and the point where the defective tissue comes to the surface of the enamel coincides with the depression on the surface (Plate 1, Fig. 1). These opaque lines are as numerous as the depressions, and in their intensity exhibit a ratio varying with the depth of the furrows upon the surface; but these do not traverse the whole area of the enamel, their extent being limited by the circumference of the enamel on one side, and the dentine upon the other passing obliquely from the surface of the enamel towards the neck of the tooth. Besides these, there are frequently in the same specimen dark bands, evidently of a similar character; and I have remarked that whenever this state of the enamel is considerable, the dentine also exhibits appearances of a departure from its normal condition, distinguishable in the form of opaque areolar markings, more or less nume-

rous; and it is *important to observe* that the point at which a line of these areolar markings approaches the surface of the dentine almost invariably coincides with that of one of the opaque bands in the enamel, both converging and meeting at the surface of the dentine (Plate 1, Fig. 2). These defects in the enamel, whenever they occur, are generally found to pervade much of the tissue, and, corresponding, as they do, with other defects in the dentine, demonstrate very clearly, I think, that the origin of the abnormal state of both these tissues is dependent upon some more or less systemic interference. If we examine the appearances of these defects in the enamel with a higher microscopic power (say one-fifth of an inch), we shall find them to consist of opaque white, and, apparently, softer material than that which exists in the more normally developed portion of the same structure: they are probably due to more than a single cause.

7. *Arrest in the Development of the Enamel.*—In some instances, they are evidently the result of a check in the progressive development of the tissue, since it is observable that each individual column of enamel recommences its growth without being continuous on that part which preceded it, and, moreover, frequently diverges into a different direction, as is shown in Plate 2, Fig. 3; and this section also shows that the opaque line of defect (*a*) consists of small spherical masses, each being not

larger in its diameter than that of a single fibre of enamel, and more or less imperfectly coalescing.

8. *Abrupt Curvatures in Enamel Rods.*—In other instances, they appear rather to result from abrupt curves in the enamel columns themselves, the opacity probably being due to a defective arrangement of the calcareous salts within the enamel sheaths, and the consequent deflection of the light in its passage through the section of enamel. These bands, however, are generally less defined in their outline and less intense in their character, and a variation in the position of the light will considerably modify their aspect.

9. *Imperfect Lateral Union between the several Columns of Enamel.*—Other defects appear to be due to an imperfect lateral union of the several columns of enamel with each other, and I think it is to this circumstance (as shown in Plate 3, Fig. 4, being a portion of Fig. 1, Plate 1, more highly magnified), as well as to a defective arrangement of the salts in the enamel sheath, that the presence of the striæ, corresponding with the minute depressions to which allusion has previously been made, is due. (Paragraph 6.) The nearer to the outer surface of the enamel, the more strongly marked are the unfavourable conditions, as if the vital force were becoming more feeble towards the completion of the structure, and the minute depressions themselves are but evidences of a failure of

power in the last effort of development. The failing force which at last ceases to build and compactly unite together the enamel columns, appears also to have lessened power in the arrangement of the salts within the sheaths of the enamel columns themselves. It is to this circumstance more than perhaps to any other that the white opaque appearance of the structure at this point is due,—the phosphate of lime probably remaining in an amorphose condition, instead of assuming the more consolidated character of the normally developed enamel. It is to this state of the enamel that I think we may trace those soft, white, opaque spots or blotches that we occasionally find on the surface of teeth, and account for the rapidity with which these same are worn down or capable of being cut into.

10. But under very different conditions of the tissue, defects may exist, arising from imperfect lateral union of the separate fibres of enamel, as well as from a defective arrangement of the salts.

11. *Development of Enamel.*—In order to exhibit this the more clearly, it is necessary that I should dwell a little upon the development of the tissue. Whichever may be the most correct of the theories brought forward to account for the plan by which the tissues of the teeth are formed, there is no doubt but that the enamel columns are built up in a longitudinal manner, and that nucleated cells, in some way, are actively connected with the production of the tissue. Each fibre of enamel is

uniformly of the same diameter at the outer as at the inner surface of the tissue, and passes, normally, in an imperfectly spiral condition, from the dentine to the surface of the enamel (Plate 2, Fig. 3, and Plate 4, Fig. 6). In the fulfilment of this plan it must necessarily follow that since the external surface of the enamel is greater than that of the surface of the dentine on which it rests, there must be some mode by which the number of these columns is increased, since otherwise there would be an increasing interspace between every column, upon its approaching the periphery of the tooth. How these interstitial columns have been produced has hitherto not been ascertained. Some time since, having a young monkey for the purpose of dissection, I embraced the opportunity of examining the development of the dental tissues. Without looking for anything particular, I observed that some of the enamel columns were, towards their growing extremity, occupied by single nucleated bodies, but that others had two placed side by side, enlarging therefore the diameter of the enamel, and producing a forked division (as shown in the accompanying drawing, which was made with the assistance of a camera lucida) (Fig. 7). Thus

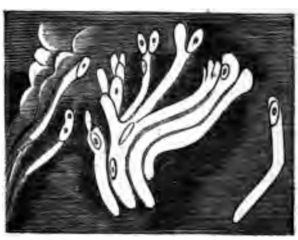


FIG. 7.

each column that contains a double nucleated

cell is capable of branching out into two, and this again and again, if required to fill up the intervening spaces. Now it must evidently follow that, in those teeth where there is a feeble or defective power of development, either arising from some systemic or local influence, that occasionally the power of producing these double branches may fail, and the result must necessarily be a defect in the development of the enamel. It is probably to the inability to produce these double cells that the deep fissures on the crowns of honeycombed teeth are due.

12. *Interspaces between the Columns at the Base of the Enamel.* — There are, however, some instances of defective union of interspaces, of more or less importance, between the enamel columns, for which the preceding explanation cannot account. The appearances shown in drawing (Plate 4, Figs. 5 and 6) must have been frequently observed, but I am not aware that they have ever been alluded to or explained in any work upon the subject. They consist of fissures, originating at the surface of the dentine, and traversing the enamel in the direction of the column, occasionally to a very considerable distance into the tissue, but most commonly to about one-third of the thickness of the enamel. The circumstance of its commencing immediately from the dentine, demonstrates that the defect must have been induced from some cause exist-

ing at the origin of the development of the enamel. An examination of these fissures shows that while they follow the direction of the enamel, the columns which build up the structure pass from the dentine to the surface of the tooth in a somewhat spiral course. These fissures are sometimes very numerous, and I am able to account for them only on the following hypothesis.

13. *Mode of First Deposition of the Enamel on the Surface of the Dentine.*—When a tooth is in the early stages of development, the enamel is first deposited on the dentine at the apex, and increases over the surface in an equal area on all sides; but its progress is not in a continuous ring round the tooth, but by a series of short unconnected longitudinal lines (Fig. 8), that, as they progress in length, increase in breadth, and, coming into contact, unite completely, under normal conditions; but, where the power of development

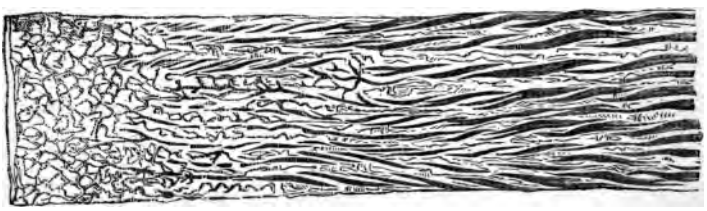


FIG. 8.

has been weakened from some unknown cause, the union is not perfect: hence the presence of those fissures at the very commencement of the development of the enamel. These appear-

ances may readily be observed, with the assistance of a very low magnifying power, in the teeth of almost any animal; but perhaps more conspicuously in the calf than in man, in consequence of the larger size of the organ.

14. *Enamel of fossil Reptile compared with immature recent Enamel of the Higher Animals.*—It may be instructive here to notice that, upon this very peculiarity in a fossil tooth (Fig. 9), Professor

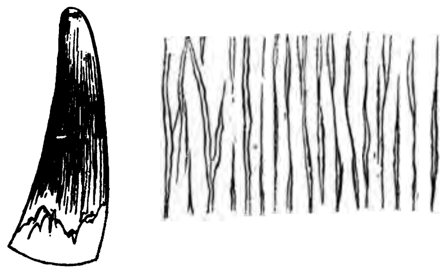


FIG. 9.

Owen established a distinct genus of extinct crocodile* (Marmorosaurus). Here we have an interesting example of a tooth being perfected in its character in an extinct species, upon the type of an undeveloped organ in the higher group of recent animals. But whatever may be the origin of these fissures, it is very evident that they must have considerable influence in the destruction of the enamel.

15. *Increasing Size of Interspaces between the Enamel.*—Examination of these fissures shows that they have a tendency to enlarge as they proceed

* Owen, "Odontography," p. 291.

into the enamel, and then again to become gradually obliterated. (Plate 4, Figs. 5 and 6). The first is in consequence of the divergence of the enamel columns from each other as they proceed towards the periphery of the tooth, and the second is probably dependent upon the development of new enamel columns. But it is highly probable that in enamel under such conditions the lateral union between the walls of the several columns is never so perfect as in a well-developed organ.

16. It is more than probable that whenever there exists a condition sufficiently strong to interfere with the normal development of either of the dentinal tissues, the influence as much affects the arrangement of the salts as it does the growth of the gelatinous tissues.

17. *Plan of Arrangement of the Salts within the Enamel Fibres.*—The minuteness of the material with which enamel sheaths are filled must considerably impede the accuracy of observation, but I am inclined to think that the section from which Plate 5, Fig. 10, is made may throw some light upon the subject. With the aid of one of the higher powers of the microscope, those enamel columns that have been cut in horizontal or oblique sections are seen to have the contents of each column arranged in layers corresponding with the circumference of the enamel sheath.*

* The author thinks it but right to state that his friend Mr. Chas. Stewart, on whose opinion he has great reliance, thinks that these

This fact I was able to determine by the examination of a considerable number of examples exhibited in the section from which the drawing was taken, some of which were cut directly across, others exhibiting a transverse section, while, again, they may be found cut in a line nearly parallel with the axis of the column. The conclusion to which the examination of this section has led me is, that the salts are deposited within the sheaths of the enamel columns, layer by layer, and that the striæ exhibited in this section are the result of a defective union between each successive layer.

18. Turning from this section to the one from which Fig. 3, Plate 2, was taken, I could clearly distinguish lines that appeared to me of a similar character, traversing each enamel column in a longitudinal direction (Plate 5, Fig. 10*a*); leading me to the conviction that these several layers correspond with the longitudinal direction of the column. But in the same sections some parts are apparent that exhibit signs of a more decided interruption in the progress of development. Wherever this has been the case, the appearance is as if the substance of each column of enamel has a tendency to break up into nodules (Plate 2, Fig. 3, *a*) of the same diameter as the columns themselves.

internal striæ may be the result of optical effect; but, since they remain constant upon the change in the position of the light, he hesitates to affirm, contrary to the author's statement.

19. *Rainey's Experiment.*—It is well here, perhaps, to dwell a moment to consider how far these appearances may correspond with the theory of the development of osseous tissue, suggested by Mr. Rainey's experiments of the consolidation of the phosphate of lime when dissolved in a gelatinous fluid. It is scarcely to be supposed that experiments, performed under circumstances obedient to chemical and physical laws only, would, without considerable modification, be preserved when brought into connection with vital laws, but whenever that force is feeble or interrupted, the inorganic or chemical law increases in action.

20. *Chemical Laws overruled in Design.*—The natural tendency of the dentinal salts, existing in the fluids that permeate the organ, is to obey their common law; but the Divine plan in building up the tissue is, that the sheath of every enamel column should be filled with bone-earth: therefore the salts, instead of forming globules, arrange themselves in layers within the walls of the sheath of each enamel fibre. When this is perfect in its completion, the salts form an apparently homogeneous mass; but if this arrangement has been interfered with, through any loss of force on the part of the vital powers, then there would be a tendency to return to the chemical laws of inorganic matter. Any departure from the homogeneous condition of the contents of the sheath will be in direct proportion to the amount

of interference in the organ at the period of development, commencing first in the exposure of the striæ between each layer of dentinal salts, and then in the arrangement of the earth in a more or less globular form.

21. *Deterioration of the Structure of Enamel towards the Outer Surface.*—The enamel in its perfected condition is the least under the influence of vital force of all the tissues that build up a tooth. The enamel organ as the tissue approaches completion *gradually* disappears; it must therefore follow, as a natural sequence, that the vitality of the organ gradually decreases in a direct ratio with the growth of the enamel. It is therefore legitimate to assume that where there is any abnormal condition in the general constitution, or defective power in the organ itself, the enamel will be less perfectly formed the nearer it approaches to the surface of the tooth. This deduction receives strong corroboration from examination of the enamel in the tooth of the elephant, as shown in the accompanying drawing (Plate 6, Fig. 12), where a gradual deterioration of the enamel is seen as it approximates the cementum, and at those places where the cementum dips the deepest, the enamel is most defective. I think that this fact demonstrates the close connection that exists between the cementum and the enamel, a connection which appears to me not to have been fully appreciated, but which it is

of importance should be rightly understood, in order to comprehend some of the conditions that are likely to exist in human teeth dependent upon an abnormal condition of the organs from which they are developed.

22. *Cementum.*—The term cementum is, in my opinion, an unfortunate one, since it only exists in the light of a cement or binding tissue in the teeth of graminivorous animals; while it is intended to include also a large and important structure in the teeth of the lower forms of mammalia, as well as an abnormal growth upon the fangs of human teeth, and also the delicate membrane that covers the crown of human and other teeth, and which exists, as correctly observed by Mr. Tomes, on those teeth which have an external investment of cement.

23. *Correspondence between the Quantity of Enamel and that of the Cementum is inverse.*—According to the size of the tooth, *it may be laid down as a law,* that the enamel exists on teeth in an inverse ratio to the cementum. In comparative anatomy this is capable of demonstration. The teeth of the walrus, dolphin,* bottled-nosed whale,† (hyperoodon) gangetic dolphin,‡ and fossil zeuglodon,§ in all of which the cementum is largely developed, have the enamel existing only

* Owen's "Odontography," p. 346.
† Owen, *l. c.* 349.
‡ Sir Everard Home, Phil. Tran. 1818.
§ Owen, *l. c.* 362.

at the extremity of the sharp-pointed crown, and is speedily worn away. Rising to the higher groups of mammalia, we find the most perfect development of enamel to exist in what I believe to be the most perfectly-developed teeth, that is in the carnivora and man: here the cementum is least.

24. *Relation between the Origin of the Enamel and Cementum.*—It appears to me that the organ from which the enamel is developed, and the cementum produced, is one and the same; that enamel will continue to be developed as long as sufficient power exists in the organ to fulfil its highest purpose; but as the growth of the dentine progresses, the tooth is pressed against the integuments of the mouth, and the vessels become depauperized and cease to keep up the supply of blood to the organ. Cementum, therefore, will be found to exist most in those teeth where the growth of the dentine is rapid, or where deep convolutions are formed in the surface of the enamel.*

25. In man (truly speaking) there is no cementum overlying the crown. In a normally-

* I think that it may be considered that the cementum in the lower organized mammalia, such as cetacea, bruta, &c., represents the true enamel in the higher orders, an arrest of development having taken place at a certain stage. It therefore holds, in its relation to enamel, a character analogous to that which the skeleton of the cartilaginous fish (both recent and fossil) holds to the skeleton of those fish which possess a bony structure.

developed tooth, the entire organ has been converted into enamel, and the only evidence of it that remains exists in a thin structureless membrane that is early destroyed through the agency of detrition and other mechanical actions.

26. *Presence of Cementum in Man dependent upon Abnormal Influence.*—But in those teeth where there has been some abnormal influence in operation, whether arising from any undue stimulus exciting the dentine to a rapid development, or from a sluggish or defective action in the power of the enamel-pulp to fulfil its object, which naturally becomes more feeble as it approaches completion, it follows that the more defective will be the enamel; and we have every right to infer that, in extreme cases, some portion of the enamel organ may remain undeveloped, and assume the character of true cementum as it appears in the lower animals. I have never met with this condition of the structure myself, but corpusculated cementum, under such circumstances, has been observed by Perkinje* and Tomes.†

27. *Cementum resulting from Injury during the Development of Enamel.*—Although I have never seen a corpusculated structure, yet I have observed its presence under parallel circumstances.

* Owen, "Introduction to Odontography," p. 12.
† Tomes, "Manual of Dental Surgery," p. 271.

(Plate 7, Fig. 13.) The accompanying drawing represents a section of part of the crown of a tooth that had received an injury during the progress of its development; the upper portion of the crown being dislocated on its axis, the result was a fracture of the enamel, the ends of the fracture separating from each other: the consequence is that the enamel organ has ossified in the character of cementum as it exists in the teeth of graminivorous mammalia, more closely than I have ever seen it either figured or described. I say the cementum of graminivorous mammals, in preference to that of the megatheroids, cetaceæ, &c., because in the former the tissue overlies an enamel, whereas in the latter there is none; the cementum being separated from the dentine by a well-marked but regular line only. Over enamel, the cementum is separated from the former by an uneven line formed apparently of nodules, each nodule generally carrying a well-marked corpuscle. In the human tooth to which I allude, the nodular condition of the tissue is present, as well as numerous corpuscles also. This decided and well-marked condition of the tissue probably occurs but seldom, and perhaps only as the result of injury, as in the present instance.

28. *Cementum in Deep Fissures of Human Teeth.*—But it is not uncommon that we meet with deep fissures in the enamel where the normal

tissue appears more or less suddenly to have ceased to be developed, and its position occupied by one of less perfect construction. Into this tissue may occasionally be traced a continuation of one or more of the enamel columns in an impoverished condition (Plate 8, Fig. 14), gradually passing from a highly calcareous structure, into one of a semi-membranous character, which undoubtedly is the permanent feature of imperfect development (Plate 8, Fig. 15). Occasionally this is found to exist to so great an extent that the corresponding enamel can scarcely be said to be developed at all.

29. *Classification of Abnormally Developed Enamel.*—The study of the more important departures from the normal condition of enamel may be arranged under the following heads :—

1st. Defect in the Organic Base—

Want of lateral union in the enamel columns at their base.

Imperfect development of secondary enamel columns.

Feeble union of enamel columns near the surface.

Presence of a semi-membranous tissue or cementum on the surface or in the crevices of enamel.

2nd. Defect in the Inorganic Base—

Imperfect arrangement of salts within the sheath of the enamel columns.

Defect in the quantity of salts.

Defective proportion of phosphates in relation to the carbonate of lime.

These several conditions appear to lead to one common result,—decrease of the mineral in proportion to the animal constituents of the organ.

30. *Imperfectly Developed Dentine.*—It is not necessary, for the purpose of demonstrating the theory of dental caries, that we should critically examine the various problems of the development of dentine. It is sufficient for our purpose that we accept the acknowledged facts, that dentine is tubular in its structure, that in a healthy condition it is in vital connection with the body, that it is nourished by an imperfectly circulating fluid, and that the tubuli are occupied by membranous fibrillæ,* that may not be tubular, but which probably line the walls of the tubuli.

31. *Nodular or Areolar Dentine.*—The most important departure from the normal character of dentine, as described in Par. 4, is that which is attributed by Tomes to the presence of an areolar tissue permeating the structure, but asserted by some to be the spaces left between the nodules of imperfectly developed tissue. Be the cause of this appearance what it may, there can be little doubt but that it is the result of some abnormal condition of the developing power of the organ.

* Tomes, "Manual," p. 286.

32. *Areolar Dentine a Reptilian Character.*—This most probably is superinduced by an unhealthy systemic condition, inasmuch as it almost invariably accompanies a defect in the enamel, and, as previously stated (Par. 6), the more prominent lines of both are found to correspond (Plate 1, Figs. 1 and 2). It is, moreover, both instructing and interesting to observe that this abnormal condition in the dentine of the highest type of tooth structure is found to exist, as the normal character, in the teeth of some reptiles and the lowest class of mammalia, in all which the teeth are protected by cementum or enamel of a less perfect character. This would seem to suggest the idea, that the areolar or nodulated condition in human teeth is an impoverished structure, being a return, on the part of Nature, to the character of the less perfect tissues existing in the teeth of the lower types of animals.

33. *Imperfect Dentine co-existent with Imperfect Enamel.*—To unassisted vision, this character of the human tooth, when recently cleft or sawn in twain, exhibits on the surface a highly silky appearance, and the more important parts of the areolar structure may, by a low magnifying power, be observed to be arranged in striæ, corresponding generally with the circumference of the dentine, and visible as opaque white lines. It is these teeth that are the most sensitive to external impressions, and I

have indubitably been able to ascertain that the white or opaque striæ are the seat of the most acute sensation.* The presence of this areolar condition of the dentine appears to exist in an inverse ratio with the perfection of the enamel, and so closely connected is it with the history of caries that I am inclined to believe that it is universally present in teeth that rapidly decay.

34. *Secondary Dentine.*—It appears to me that the study of secondary dentine may throw some light upon the history of the development of this nodulated structure, and consequently upon the pathology of dental caries. My drawing (Plate 9, Fig. 16) is the section of a tooth that was considerably decayed before it was filled with cadmium: after a period the stopping gave way, the tooth pained, and was extracted. Upon splitting the tooth the healthy dentine was found to be deeply stained pink, from the infiltrating into the structure of the decomposed particles of the red corpuscles of blood. The dentine that was within the limits of the disease was not discoloured from this cause, but at one point, a broad line of yellow, the result

* I arrived at this conclusion through the following observation:—Having to plug a cavity in a tooth, I was able to succeed in cutting out all the caries, and leave the dentine bare, with tolerable ease, one point alone being sensitive. Upon wiping out the cavity, I could, by the aid of a pocket lens, distinctly see the opaque white striæ, indicating the presence of the areolar structure. I carefully ascertained, with the point of a firm instrument, that to touch this striæ was to give a distinct sensation of pain, whereas all round was not conscious of any feeling.

of sulphuret of cadmium, appears to have penetrated the tubuli nearly to the pulp cavity;* two or three less conspicuous but similar places appear to have been influenced by the same cause. Corresponding with each of these lines, a deposition of secondary dentine has taken place (Plate 10, Fig. 17) : this is more particularly visible in the larger. Upon examining a section of this tooth under a higher power, we find that a line of structureless tissue separates the older from the more newly deposited dentine, showing that the sulphurate of cadmium had actually penetrated to the then existing pulp cavity, and stimulated it into action.

35. *Nodulated Dentine induced by Sulphuret of Cadmium.*—The instructive portion of this section appears to arise from the following circumstances. At the point nearest to the yellow stain the new dentine is developed in a nodular or areolar condition (Plate 10, Fig. 18); and this character is also traceable in smaller nodules along the margin of the newly-developed tissue; but everywhere else the character of the structure is that of tubular dentine; and it is curious to observe that in accordance with the increase of its distance from foreign influence, the nearer it resembles the normal character of dentine, until it ultimately appears to be a continua-

* This fact suggested to the author of this paper a plan of treating dental caries which is given in the Appendix.

tion of the primary structure, the tubes possessing only a slight deflection in their passage, whereas at all other points there is not only no connection between the two, but the tubuli of the secondary dentine commence generally in loops, as if it were an independent structure.

36. I think that the following conclusions may be safely deduced from the appearances in the development of the secondary dentine in this specimen:—

1. That the new tissue was stimulated into development by the presence of sulphuret of cadmium.
2. That the stimulus was greatest the nearest to the cadmium.
3. That it was weakest at the points most distant from it.

I therefore infer that, since the secondary dentine which is developed most distant from the stimulus assimilates in appearance more closely to that of the primary structure, it must also approach more nearly in its formation to the normal conditions of the development of dentine. I think, therefore, that we may assume the nodulated tissue to be the result of the presence of the cadmium, and that it is a too rapidly developed tissue.

37. *Nodulated Dentine induced by Caries.*—I think that these inferences receive support from the section of another tooth, in which

the nodulated structure is shown, to a very considerable extent, in the midst of a mass of transparent secondary dentine. In this case, I imagine, from the absence of all other causes, the stimulus to have been caries: in the early progress of the disease, the secondary tissue was developed as a transparent structure, but as the disease increased, the stimulus became greater, and terminated in a mass of nodular structure. That this was the ultimate point of development I think is demonstrable from the circumstance that there are two examples in this tooth, and in both the dentinal tubes radiate from the nodulated structure (Plate 11, Figs. 19 and 20).

38. *Nodulated Dentine the Result of Abnormal Activity of Development.*—It appears to me that this nodulated appearance under the circumstances just related throws considerable light upon the presence of the nodulated or areolar form in primary dentine. This structure in dentine is invariably connected with abnormal action, which I think we may now justly infer to be the result of an overactive development, arising probably from some constitutional disturbance. This appears to receive corroboration from the circumstance that the honeycomb teeth in which this abnormal appearance is most prevalent are generally erupted at an earlier age than the more normally developed organs.

39. *Dentine less liable to Variations than Enamel.* Dentine is less liable to many variations of

defective structure than enamel, and generally improves in character as it approximates the pulp, a circumstance that may be attributed to its different plan of development. In the dentinal pulp, as in that of the enamel, the power of development must diminish in force as the structure approximates completion; but there is this important distinction, that whereas the area of the enamel increases, that of the dentine diminishes with the progress of development. The consequence is that the effort of the latter is less taxed when it is least able to fulfil the condition.

40. We occasionally see perforations and defectively developed tubuli in dentine, but they are so exceptional that they can have but little influence in the pathology of dental caries.

41. *Raschkow's Membrane.*—There is one tissue of little structural appearance in a tooth, but of great importance in its pathological history, that has not been sufficiently studied by writers on the subject. I allude to the membrane that separates the enamel from the dentine. It will be found to be an invariable rule, that in the best developed organs the dentinal tubes never pass beyond this intermediate membrane; but in those teeth where we find defective tissues, the tubuli of the dentine frequently either pass through or are in connection with interspaces in the enamel. Under this latter circumstance the membrane must be considerably impoverished

and deficient in structure, while in the former it probably forms a homogeneous membranous tissue.

42. I speak of this tissue as being as distinct from both enamel and dentine as that which overlies the enamel, and with which it comes into contact at the neck of the tooth. It is not only a membrane during the development of the tooth, and therefore present in theory only in the perfected organ, but it is capable of being dissected out and distinctly shown, as in the accompanying drawing (Figs. 21 and 22). The more or less

FIG. 21.

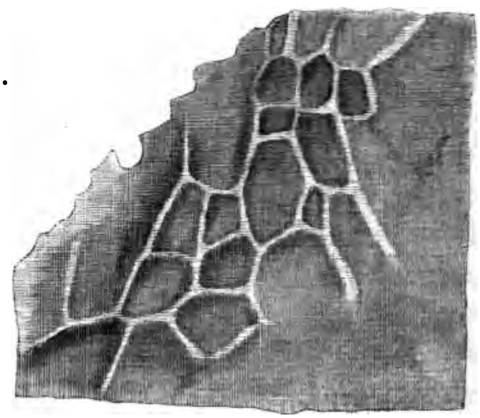


FIG. 22.

perfect condition of this membranous tissue must form an important feature in the history of dental caries, lying as it does at right angles with the tubuli of the dentine as well as to the direction of the enamel columns.

THEORY OF DECAY.

I have shown in the foregoing pages the most important of the common aberrations in the development both of enamel and dentine, because the progress of caries is intimately connected with them.

The enamel, being external to the dentine, affords, when perfect in its character, a strong protection to the latter from external influences; but, inasmuch as the development of both tissues is synchronous, it follows that every systemic affection that acts upon one tissue must, in a great degree, influence the development of the other. Therefore, in those cases where the enamel has not sufficient strength to resist the action of external influences, the dentine is in a condition that is equally ready to be acted upon by the same agents; and I think that it may be accepted as a constant result that the less the enamel has been able to resist destruction, the more rapidly will the disintegration of the dentine take place.

There is no peculiar place or part of a tooth in which the decomposition of the dental tissues shall commence. The most frequent positions are in the deep crevices on the crown, at the points of contact between closely approximating teeth, at the necks of teeth which have been denuded of the gums, and on the outer central surface of

front upper teeth. It will occasionally occur in many other places, such as the apex of a tooth, but where it commences the least frequently is on the inner or lingual surface of all teeth, except perhaps the upper incisors.

The plan upon which the disease progresses is, by commencing upon the outer surface of a tooth, and gradually passing through to the base of the enamel, where it immediately increases on the surface of the dentine; it then, rapidly, in comparison, extends both in circumference and depth, and proceeds until the whole structure becomes involved in decomposition.

It is here desirable that we should clearly see in what is the immediate commencement of the disease.

Over the surface of the enamel, that extremely thin tissue which is called cementum exists during the earlier years after the eruption of the tooth.

This cementum, which is speedily removed by friction, &c., from the smooth and even surface of the enamel, is not brought under the same influences when folded in the deeper crevices of the organ (*vide* Par. 28), where it is not only present, but thicker than over the surface of the crown.*

* "In some cases," Mr. Tomes says, "the deep crevices are filled with cementum; in others they have been occupied until the tooth has been cut, and then been filled with tartar, but more commonly they become the seat of caries."—Tomes's Manual, p. 275.

The enamel can be said to hold but a limited vital connection with the body; therefore this structureless membrane that overlies the enamel can have but a feeble vitality, and is associated, rather than connected, with the living organism.

The consequence is, that this tissue dies rapidly under the least unfavourable condition. We see that this is the case, since, in those mouths where it has not been previously removed by friction, it assumes a dark green colour as it decomposes. If we examine a tooth which has been so circumstanced, we shall perceive that the enamel immediately beneath, and which appears to have been otherwise of a strong and well-developed character, rapidly undergoes disintegration, and this not in any crevice or hollow, but over the smooth surface of the structure, and extending as far as the decomposing external membrane has influence.* At the necks of teeth, decay commences where the gum has receded and friction is not employed: the discoloration as the result of decay commences immediately, and this not in any pit or crevice, but on the central or most rounded part of the fang. The fang, we know, is covered by an ossified membrane that is the

* Negative evidence can only be accepted for what it is worth; but I believe it to be a fact, that after the removal of the cementum from the surface of the enamel, caries never commences upon the middle of the anterior surface of upper front incisors or canines.

homotype of that which overlies the enamel. We therefore perceive that caries here also commences in the same tissue: between the teeth we see that it is this same tissue which is first attacked by decay; and not unfrequently it may be observed, in well-developed organs, that decomposition may proceed no deeper, but remains during the existence of the tooth as a discoloured spot on the surface of the enamel only,—demonstrating that a position which may be favourable for the commencement is not always that which is most favourable for its further progress.

By a parity of reasoning, we may infer that in the deep crevices, in which we know by observation (Plate 8, Fig. 14) that this same membranous tissue exists, it is the first to perish. Assuming, therefore, that in these crevices the decomposition of the cementum admits of the same deleterious influences on the underlying enamel as we perceive it to have on the surfaces of the upper incisor teeth, it follows, since these crevices are invariably the result of a defectively-developed tissue, that the enamel underlying the cementum is in a condition most favourable for the rapid progress of its decomposition. I have seen some of these filled with tartar, as has been noticed by Mr. Tomes, but I am inclined to think that this deposit seldom occurs in this position. I think so, because in those mouths where the teeth are in their defective development, the

most favourable for the rapid progress of caries, salivary calculus is deficient in the saliva. But its presence in these crevices may account for the circumstance that apparently similar defects are not always similarly affected by decay.

I think that the relation existing between the absence of the deposition of tartar, and the presence of a defective development of the dental tissues, exhibits a very close dependence of the decomposition of the dental tissues upon the normal condition of the systemic constitution.

I contend that the immediate commencement of dental caries consists in the death of some portion of carbonized tissue, in direct contact with the enamel; and, in the most frequent instances, that tissue is the so-called membranous cementum that overlies the enamel and that portion of the fang that is left unprotected by the gum.

It has therefore been observed that the disorganization of this tissue occurs frequently upon the front of the superior intermaxillary teeth, and that its presence is almost invariably the cause of the decomposition of the underlying enamel.*

To establish a theory that will account for

* Dr. Chappin Harris says, in writing of it as tartar, "Its resemblance is more that of a stain on the enamel than salivary calculus. Children and young persons are more subject to it than adults, though it is occasionally observed on the teeth of the latter. It is exceedingly acrid, and has the effect of decomposing the enamel."—PRIN. AND PRAC. OF DENTAL SURG., p. 252, 3rd edit.

dental caries, it must be based both on deductive reasoning and experimental evidence.

Mr. Tomes has truly remarked that the appearances as exhibited in the decomposition by caries of the dentine cannot be reproduced experimentally.*

But the same remark appears to me applicable in relation to the enamel also, for experiments are generally conducted upon thin sections of teeth, and chemical action is brought to bear unduly upon the lateral walls of the separate enamel columns, the membranous structure of which has already probably been injured or rubbed away. I therefore think that such experiments are liable very much to mislead observers.

The cementum that overlies the enamel retains its organic connection with the tooth through a feeble attachment to the tissue existing between the enamel rods, the extremities of which it covers and protects, offering, it appears to me, a strong *primâ-facie* argument that there exists a powerful opposing means to the action of any free acid that may be present in the saliva,† no matter whether

* "Man. Dent. Surg.," p. 310.

† It is highly probable that lactic acid may, upon closer research, be found not to exist as a constituent in healthy human saliva. Lehman, in his "Phys. Chemistry," p. 49, says that he has never been able to detect lactic acid in normal saliva of man or the horse, but he has, beyond all doubt, in the saliva of a patient suffering from diabetes mellites. It was formerly believed to exist in urine, but, from the researches of Liebig, it appears that a peculiar azotized compound, which is not entitled to the designation of an acid, but which forms a

it be lactic acid, or such as may be taken into the mouth with food.*

But we find that decomposition takes place beneath the membrane. It cannot be admitted that a free acid must have passed through the membrane, for the condition necessary to admit of the action of endosmose is wanting, in the absence of a second fluid of different density, the enamel being impervious to moisture. And, moreover, we find that in those teeth where the cementum is absent or not decayed, and where, in equally neglected mouths, a free acid would appear to have power to act upon the lime of the tooth more directly, it does not act at all.† Certainly a free acid would be as direct and powerful in its action in those instances where the cementum is removed as where it is present.

We find, moreover, that other portions, both above and below the discoloured mucous-like surface, and where the acid might equally penetrate, remain uninjured.

These circumstances induce me to believe that whatever be the destructive agent, it will be found to exist as the result of that action which induces the discoloration of the membrane of cementum.

definite combination with zinc, has been mistaken for it.—CARPENTER'S MAN. PHYS., p. 428.

* Tomes's Lectures on Teeth, p. 211.

† So constant is this rule, that, to superficial observers, it gives force to the expression of Mr. Robertson in his theory that "teeth never decay upon a smooth surface."

The cementum in its most perfectly developed condition is not a highly calcified tissue,* and, judging of its aspect by the assistance of a microscope, it is less so in man than in animals.

Its low vitality admits of its early death, and it is to this cause, I believe, that discoloration is to be attributed—being that of decomposition, and, analogous to the dark appearance of decay in dentine.

Decomposition of animal tissue having commenced, the immediate and one of the chief products is carbonic acid.

The creation of this acid within, as it were, the tissue itself, and therefore brought in its nascent condition into juxtaposition with the salts of the tooth, must act with more direct power, and reduce the salt to a soluble condition. The removal of each atom of phosphate of lime, in its turn exposes more of the animal tissue of the enamel to decomposition, and an increased chemical action is superinduced.

To support the assertion that the removal of the salts of the tooth is due to the action of *carbonic acid*, it is necessary that I should establish it by experimental evidence.†

* According to the analysis of Lassaigne, the quantity of animal matter in the "cortical substance" (cementum) is 42·18, whereas Berzelius states that of the "osseous portion" (dentine) to be 28·0.—Bequerel & Rodier, l. c. p. 516.

† The author of this paper placed a section of a tooth in a glass of distilled water, and passed into it carbonic acid generated in another

In 1846, M. Lassaigne, in a communication* "On the mode in which phosphate and carbonate of lime are conveyed into the organs of plants, &c.," announced to the Academy of Sciences at Paris, that water saturated with carbonic acid at the temperature of 50 F., and under the mean pressure of the atmosphere, dissolves the phosphate of bones in proportion of $\frac{75}{200000}$ of its weight.

M. Dumas has also made researches upon the subject, but I have not been able to obtain his results.

Mr. Gore has recently shown† that carbonic acid in a liquid state is capable of dissolving white phosphoric acid.

Among analytical chemists, the fact of the power of carbonic acid to dissolve the phosphate of bone is, I believe, accepted as established. It will therefore be for me only to show the source of the carbonic acid, and that it exists in quantities sufficiently great to act upon the salts of the tooth, so as to reduce them to a soluble state, in order to fulfil the conditions necessary to establish the theory, and which, if it coincides with all known laws in chemistry and physiology, must be accepted as true.

vessel. The result was, that in a short time (a week or so), nearly, if not quite, all the lime was removed; but the author not being a chemist, hesitates to rely upon the experiment, as there may have been conditions to vitiate the experiment that he could not appreciate.

* "Medical Gazette," December, 1849.

† Phil. Trans. vol. cli. p. 86.

It may be stated as an objection that the free CO_2 is so feeble an acid that it can dissolve but a very small quantity. I take this to be precisely an argument in its favour.

Every practitioner will bear me testimony that frequently parts of the teeth placed under circumstances most favourable to decay will resist the action for many years, or perhaps altogether; and, under the most rapid action of the disease, the time that is taken for the removal of the salts from the structure is considerable, when compared with that which an experiment upon similar substances would take in the laboratory.

I believe that by the decomposition of the animal tissue upon the surface of the enamel carbonic acid is generated; that at the period of the union of the carbon with the oxygen existing in the saliva at the very birth, so to speak, of CO_2, it acts upon the bone-earth that is in immediate connection with it.

I have in the previous portion of the paper shown that there is a tendency in the development of enamel to deterioration as it approximates towards the surface, and that the tendency of every species of deterioration is to admit of a preponderance of the organic constituent of the enamel over its normal relation to the inorganic. Thus I presume that if the enamel immediately beneath this defunct cementum is defective in its development, the death of the external membrane

extends to that with which it is in connection; and for the removal of every atom of lime so much more of the animal structure becomes exposed to decomposition: for so low is the vital force within the enamel, that unless the normal balance between the organic and inorganic constituents of the tissue be preserved, both are subject to the full force of chemical laws.

This, which takes place over the smooth surface of the incisor or other teeth, is more frequent and rapid in its progress in the deep abnormal crevices and fissures of molar or other teeth. In these crevices, I believe that the membranous tissue that overlies the enamel is generally present, and that the enamel is frequently so imperfectly developed that it passes gradually into the cement tissue.

I do not consider that it is absolutely necessary that a fragment of cementum should be retained in any position in order to induce decay. The presence of dead animal matter is sufficient; and I believe that this is generally the case in those mouths where there is a large flow of thick stringy saliva. It is well known that the presence of this condition of saliva is a certain indication of a very considerable extent of dental caries. I attribute this circumstance to an increased amount of animal matter in the saliva arising from some constitutional cause and a deficient quantity of bone-earths. The following analyses from Simon

of healthy and mercurial saliva will demonstrate this to be true, as well as the fact of the general absence of tartar in this character of saliva :—

HEALTHY SALIVA.		MERCURIAL SALIVA.	
Water	991·225	Water	974·12
Solid matter	8·775	Solid matter	25·88
Fat containing chlosterine	0·525	Viscid yellow adipose matter	6·74
Ptyaline and extractive matter	4·375	Ptyaline, with traces of caseine	3·65
Extractive matter and salt	2·450	Alcoholic extract and salt	7·55
Albumen, mucus and cells	1·400	Albumen	7·77

The increase of albumen and fatty matter in the unhealthy saliva is very considerable, and these substances probably lodge in and about the crevices and interstices of teeth, and there decompose.

I am inclined to believe that the decomposition of the cementum on the extremities of the imperfectly-developed enamel fibres is the more constant, inasmuch as the birth (so to speak) of the new agent takes place in juxtaposition with the salt it dissolves.

Warmth is well known to stimulate decomposition of animal substances; it is therefore an active secondary agent in the production of $C\ O_2$. It is under these circumstances we see how commonly cooks and inhabitants of hot kitchens rapidly lose their teeth, as well as account in some measure for the fact that the teeth decay more rapidly in the posterior region of the mouth than in the anterior.

Examination of a transverse section of enamel attached to progressive caries, appears to me to show a line of discoloration between* the enamel columns, as the incipient mark of disease, (Plate 5, Fig. 11): this I interpret to be the death of the animal substance of the enamel.

This appears to me to pass on with very little comparative destruction to the central structure of the enamel columns, unless the cause of the destruction be very extensive at the surface, until it penetrates to the dentine.

Here is situated another membranous tissue as a floor to the enamel, and both by its position and structure likely to afford resistance to the penetration of an external free acid. In some animals this membrane is very conspicuous, as in the hippopotamus—in others less so; and I am inclined to believe that its tenuity is rendered extreme in those teeth in which we see the dentinal tubes pass into the enamel: in other words, we can scarcely expect to find it to exhibit the appearance of a well-developed tissue in those teeth where the other tissues have suffered structural deterioration. Its vitality appears not to be of a high degree, for it is a constant feature

* Mr. Tomes says that "the central portion of the fibre is the first to suffer decomposition, in the same manner as when the destructive agent is intentionally applied to a section prepared for experimental treat ment" (p. 308). It appears to me that Mr. Tomes has been here misled by his experiment, since, in a thin section of enamel, the acids could act upon the enamel column laterally as well as vertically.

in the progress of caries that it shall perish immediately and extensively upon being brought into contact with external influences.

As soon as decomposition reaches this membrane, however minute in its extent, the increase is rapid and extensive, proceeding, not continuously in a vertical direction towards the pulp, but traversing the area immediately beneath the enamel to a considerable extent in every direction.

Upon reaching the dentine, a larger proportion of animal matter is brought into the field of action, and a greater amount of nascent carbonic acid is generated. Moreover, a new feature is brought into existence, and which, I believe, may be considered as an important condition in the history of dental caries.

It must have struck every observer as a curious fact, that whereas in artificial experiments the enamel is the first to disintegrate under the influence of applied acids, it should be the last to yield under the action of caries.

It is also worthy of attention, that whereas the opening through the enamel is frequently so minute as only to admit of the passage of the most subtile fluid, the decay within has been rapid and extensive, and as soon as the disease reaches the membrane at the base of the enamel, the enamel commences rapidly to disintegrate from

within outwards,* and the dentine frequently decays at a rate more rapidly than appears to be commensurate with the amount of destructive material capable of being admitted to the tissue.

The rapid progress of decay along the membrane at the base of the enamel is frequently exhibited in practice where decay has commenced at the neck of the tooth, and spread beneath the enamel, allowing the latter to break off, and leaving an extent of superficial caries underneath.

The progress of the disease is well shown in the two annexed examples.

In the one (Plate 12, Fig. 23), the enamel is excavated by disease into a hollow, larger within than without; and the membrane below is decaying laterally beyond the limits of the disease in the enamel.

In the other instance (Plate 13, Fig. 24), the external progress of decay has scarcely reached the base of the enamel, and yet, owing to a series of fissures, disintegration has spread to a considerable extent laterally without penetrating either the enamel or dentine.

It will be observed that both cavities are partially filled with tartar, this being a recent deposit, a circumstance that has probably precluded the rapid increase of the disease by the exclusion of

* Every operator must have observed how white, soft, and friable the inner layer of enamel cuts in decayed teeth, compared with the outer layer of the same tissues.

oxygen, which is necessary for the presence of decomposition and the elimination of carbonic acid.

The more *rapid* decomposition of the basal surface of the enamel, as well as the other internal tissues, than that of the outer surface of the enamel, is to me strongly suggestive of the idea, that the great destructive agent is to be found within the tissues of the tooth, rather than dependent upon external accidents.

The dentinal tubuli, as they approach the periphery of the dentine, generally inosculate with one another. This appears to me to be the common law in all animals, from the exquisitely fine tubuli of the diodon to the great folds in the vaso-dentine of the megatherium. But whether this idea be accepted or not, we know that the tubuli contain membranous fibres, which are probably canals, and that a fluid, assumed to be the serum of the blood, passes through them.

As soon as the caries has passed the membrane that is between the dentine and the enamel, the extremities of the tubuli are ruptured, and the consequence is, that the contents of the tubuli are poured out into the cavity that has been excavated by previous decay.

Passing beyond the reach of the vital force, the serum ceases to circulate, and therefore dies, and, by decomposing, produces carbonic acid. It thus appears to me that the more or less rapid progress of caries is dependent, to a great extent, upon the

quantity and quality of the dental fluid that is so lost, in connection with the more or less normal development of the dentinal tissues.

Assuming the fluid to be liquor sanguinis, it must carry in solution fibrine and albumen, both of which are highly carbonized substances, and therefore upon exposure liable to rapid decomposition. I am inclined to think that to the presence of this fluid is to be attributed the unpleasant taste peculiar to dental caries.*

That the connection between caries and the tubuli is very close I think can be shown to demonstration. In early life, when we should suppose, from the largeness of the dental pulps, and the extent of the openings of the tubuli, that the circulation of the fluid must be the greater, is the period at which dental caries, when it exists, proceeds most rapidly. And we can perceive, moreover, a cause for the close relation that exists in some diseases with the extensiveness of decay, for should the blood be vitiated in its quality, its condition might be such as to superinduce a more rapid decomposition of the tissue.

In support of the same opinion, I would draw attention to caries as it proceeds more slowly. If we make a section under such circumstances, I

* I infer this from the circumstance that there appears not to be the same taste complained of in the decomposition of human teeth when placed in the mouth artificially, although sometimes decay may be very extensively present.

think we shall invariably find that, over however large an area the decay may have extended, it is confined within defined limits, which gradually narrow as the disease approaches the pulp, following the contour of the dentinal tubes. This appears to me to be capable of explanation upon no hypothesis but that which is here advanced (Plate 12, Figs. 23 and 25).

It seems an untenable supposition that any free acid admitted through the enamel can have less power to act laterally upon the dentinal substance when near the pulp, than it has when near the surface. The argument that it penetrates the tubuli perpendicularly will not suffice, otherwise the extent of the disease near the surface of the dentine should not spread out laterally beyond the limits of the same disease in its passage through the enamel.

The separation between those tubuli in which the circulation of the fluid is still normally continued, and those that may be said to bleed at their extremities, is defined by a distinct line of demarcation.*

This line that marks the boundary of the disease is very decided: it is distinct in its character from the rest of the structure, and appears to be an effort on the part of Nature to

* This line must not be confounded with that transparent areola that surrounds decay, and which Mr. Tomes considers to be consolidation of the dentinal tubuli.

arrest the lateral spread of the disease, probably by a deposition of matter. Its external limit corresponds with that of the death of the membrane at the base of the enamel; and it follows the line of the tubuli, narrowing to the pulp.

This effort of Nature appears to be useful only anterior to the disease having reached the pulp cavity, and is probably induced through a small amount of stimulus given to the pulp itself.

As the disease deepens, a more active stimulus is excited, which frequently results in the development of secondary dentine.

Decomposition of the outer layer is immediately followed by a change in the appearance of the extremities of the dentinal tubes, and this change is exhibited in the form of a transparent areola, circumscribing the disease.

This transparent areola has been asserted by Mr. Tomes (and I believe it is generally accepted) to be the result of the deposition of osseous material within the tubules, and therefore to be considered in the light of an effort of repair.

FIG. 26.

My own has always been at variance with that opinion, and for the following reasons:—If we examine the progress of decomposition as it

proceeds in dentine that has been inserted in the mouth in the character of artificial teeth, we find precisely the same transparent margin anticipating the progress of the decay of animal matter (Fig. 26, *a*). Now, since in an extraneous body no vital action can take place, we must assume that the transparent appearance is the result of a removal instead of a deposition of the salts.

In the removal of the salts we perceive that the first action is within the dentinal tubuli, where, I believe, the salts exist in an amorphous state, which gives them their white appearance. In the teeth of old persons it is well known that this white appearance considerably decreases, and that the tubuli almost disappear from the fangs.

According to the analysis of Lassaigne* the change of chemical structure between the teeth of an adult and an old man is due to the decrease of carbonate of lime and an increase of the phosphate and animal matter. If this can be relied upon as being universally true, I think we may hypothetically assume that the whiteness of the tubes is due to the presence of carbonate of lime.

Soon after the decalcification of the structure,

* Lassaigne's analysis is as follows:—

	Organic matter.	Phosphate of lime.	Carbonate of lime.
Tooth of a child one day old	35·00	51·00	14·00
Do. six years old	28·57	60·01	11·42
Do. of an adult	29·00	61·00	10·00
Do. of a man eighty-one years old	33·00	66·00	1·00

BEQUEREL & RODIER, p. 517.

the animal base of the tooth perishes, and whilst dying generates carbonic acid, and this actually within the tubuli, and decalcifies their solid walls.

It is this process of decalcification of the periphery of the tubuli which gives to the dentinal tubes that increased diameter during the progress of decay, as may be seen by comparing Figs. 27 and 28 with Fig. 29 in Plate 14, from the same tooth. Upon completion of the process as shown in transverse and longitudinal sections of the tissue, *the lime is entirely removed* (Plate 14, Fig. 30; and Plate 4, Fig. 31).

The removal of the lime admits of the death of organic matter to an increased amount, and consequently an increased production of carbonic acid, and therefore a consequent increase in the rapidity of the disorganization of the entire organ.

I have assumed that carbonic acid is the chemical agent for the removal of lime from the teeth, because it appears to be the only one that is naturally present,* and that its presence is continuous and permanent. It is known that a large quantity of this gas is set free during the decomposition of almost every kind of organic matter; "and that it also takes place, to a very great extent, in the period that often precedes death."†

* Lactic acid, whenever present, has only been found in combination with soda or potash. (*Vide* Note, p. 73).

† Carpenter, "Man. Phys.," p. 369.

Moreover, it is known to exist in blood,* the serum absorbing it to as great an extent as water.

If we return to the causes that remove bone and tooth structure by what is called absorption, we must conclude that whatever may be the process, the bone-earths must be carried away in solution; for, to say that it is done by absorption, is to confess we know nothing of the process. Now, whatever may be the dissolving agent, it must exist or be generated within the system; all that appears to be necessary is the absence or removal of a nominally protecting organic tissue.

Thus we see that the part of ivory pegs inserted into living bone becomes absorbed, while that without the bone remains entire.†

The same must hold true in the removal of the lime during the absorption of the fangs of the deciduous teeth.

Again, what but carbonic acid that is present in an abscess‡ can dissolve and remove the lime from the substance of the dentine ‖ at a considerable distance beneath the gum, where no agent could have access unless it existed within the system?

* The experiment of Lehmann shows that the proportion of carbonic acid in the blood is 70 per 1,000, if we merely employ agitation or other mechanical measures; and 300 per 1,000, on the addition of an acid.—Bequerel & Rodier, p. 417.

† Stanley, "Lancet," Oct. 11, 1851.

‡ Bequerel & Rodier, p. 418, l. c.

‖ The case illustrative of this circumstance is given in the Appendix.

I therefore contend that the same agent that is capable of removing the lime from living bone and teeth under the process of absorption, is also capable of removing it under the condition necessary to produce decay.

The following is a brief review of the theory here advanced: *That the presence of dental caries is dependent upon*—

1st. Abnormal or defective condition of the dental tissues.

2nd. The unhealthy condition of the blood, particularly the serous fluid; and therefore upon the health of the system generally.

3rd. The incipient progress of decay is dependent upon the decomposition of animal matter in juxtaposition with the tooth.

4th. That after decomposition has reached the surface of the dentine, the membranous tissue between the enamel and the dentine perishes to an indefinite extent.

5th. The disease attacking the dentine, the circulation of the fluid in the tubuli is interfered with, and empties itself into the cavity created by the previously decomposed tissue.

6th. Decomposition of the fibrillæ takes place within the tubuli, and therefore carbonic acid is eliminated actually within

the tissue; thus bringing a newly-created or nascent carbonic acid into immediate contact with its salts, which are then carried away in solution.

7th. The removal of the bone-earth by allowing the death of the animal substance of the dentine, its decomposition generates an increased supply of carbonic acid, and so on until the entire organ is broken down.

CONCLUSION.

The determination of the constitutional character in which the teeth are most liable to be attacked by caries is an object worthy of our consideration.

Extended observation shows that the most opposite extremes appear as if under parallel influences; that teeth apparently well developed in an individual who appears to be healthy will rapidly decay, while in another they will remain sound.

Similar teeth remain unaffected by caries in the mouth of a delicate or sickly person, whereas, again, we as frequently find them decay.

Nay, more, it is not very unfrequent that we find teeth that we know to be defective in their organic structure, will remain free from

caries; while similar teeth, under other conditions, are early attacked and rapidly decay.

If we turn our attention to the persons in whom the teeth decay most frequently and generally, we shall find that some nations are affected while others are not; that some families are affected while others are not; that some occupations are affected while others are not.

The early loss of teeth from caries among the inhabitants of the United States is a well-known fact, while among the aboriginal tribes the disease is unknown. A surgeon in one of the ships on the Franklin expedition to the Arctic regions informed me that he never saw a decayed tooth among the Esquimaux, although he made his observations on both living and dead subjects.*

In some families we see teeth in the same positions decay about the same period of life; while others, apparently not more perfect, and under the same apparent conditions, remain permanently sound.

How commonly do we find that individuals who have passed many years in India have lost their teeth! That cooks rapidly lose these organs, is a circumstance that I have perceived so con-

* Mr. Lord, the able naturalist attached to the commission sent out to establish the bouudary between Canada and the United States of North America, informed me that he has occasionally seen decay in the teeth of the Aborigines.

stantly that I believe it to be a fact, as strong as is possible without the evidence of extended statistical observation.

We are accustomed to attribute the causes of such great destruction of the teeth to the stomach. The broth of the cook and the curry of the Indian "have disordered the stomach, and decayed the teeth;" or the equally conclusive statement, "that the great and sudden variations of climate produce the same result in North America,"—these are assertions that can only be accepted as evidence of our ignorance of the true causes of these wholesale phenomena.

That there is some general law to account for these conditions is certain; and it comes within the province of dental physiologists to endeavour to discover it.

I do not believe that at present we have sufficient data on which to establish that law, but it may not be without advantageous results that an hypothesis may be suggested.

The liberation of superfluous carbon from the system appears to be an essential condition of healthy economy of animal life, no matter whether it be performed by the aid of the lungs or gills, the surface of the skin, or through the secretion of bile.

Now, it is a remarkable fact, exhibited in the animal kingdom, that the relation of the liver to the respiratory organs is inversely proportioned

to each other. Whether we observe the first development in the lowest scale of the animal kingdom, or that of the embryo of the higher grades, we shall find that the liver is the first organ of the two which is formed.

We may therefore infer that, whatever circumstance may interfere with the power of either of these organs in their due performance of their legitimate functions, must, by precluding the removal of the due proportion of carbon from the system, admit of its remaining in undue quantities in the fluids of the body. The serum is capable of holding in solution a considerable quantity; and since this plays an active part in dental caries, I think we may infer that those diseases in which the exhalation of carbonic acid is below the normal condition, are just those in which we should expect to find the teeth more liable to decay.*

The secretion of bile bears an equally important relation, in the removal of superfluous carbon. Damarcay has shown that cholic acid contains nearly sixty-three per cent. of carbon.

We must therefore believe that, should any interference arrest the secretion of this fluid, the surplus carbon must remain in the system,

* According to MM. Harvier and St. Leger, the exhalation of carbonic acid diminishes in phthisis, variola, measles, erysipelas, roseola, scarlatina, erythema, dysentery, chronic diarrhœa, typhoid fever, as well as during the suppurative process.—BEQUEREL & RODIER, "Path. Chemistry," p. 418.

and be taken up in undue proportions in the blood.

It is through this means I think we may trace the cause of extensive caries in the mouths of persons long resident in the tropics, as well as most other parallel conditions.

APPENDIX.

CASE I.—ABSCESS IN DENTINE.—*p.* 53.

Mr. P. consulted me, by the advice of his surgeon, relative to a discharge that poured out from the antrum. The discharge filled his throat when lying down, and dropped from his nose when in an upright position.

The first molar tooth was apparently sound and firm in the socket; but since the second bicuspid had been lost, it was proposed to extract the first molar, in order, if required, to make an opening into the antrum through one of the alveoli.

The tooth, which was very firmly planted in the jaw, came out well, except the extremity of one of the fangs, which remained in the jaw.

After the removal of the tooth the disease gradually subsided.

Upon making a section of the tooth (Fig. 32), I found that the pulp cavity was wholly decomposed and full of pus, the true source of the disease. I also remarked upon the side of the palatal fang a small hole, through which not being able to pass a fine wire into the pulp cavity, I concluded must be the result of an abscess in the substance of the dentine. I therefore sawed carefully through the centre, so as not to interfere with the characteristic features of the disease: by so doing, I found a cavity occupying nearly the entire width of the dentine, from the pulp centre to the periphery

c *b*

FIG. 32.

of the fang (Fig. 32, *b c*), having no connection with the central cavity, and opening externally by a small oblong orifice.

It is the removal of the salts from this cavity that I contend, in the foregoing paper, must have been performed by a solvent, generated or existing within the system; and if so, that solvent, whatever it may have been, would have the same power to remove the salts from the dentine, under conditions that are not of a more abnormal character.

CASE II.—*p*. 26.

The specimen here alluded to is that of a tooth that had been plugged with cadmium. The stopping, after a time, fell out, the tooth pained, and was extracted.

Upon splitting open the tooth, it was found to be deeply stained with the granular contents of the blood corpuscles, except that portion which was affected by disease.

The decayed portion was found in several places to be deeply stained by sulphuret of cadmium, which followed, in its passage to the pulp, the line of the tubuli, and which in every instance more or less actively stimulated the deposition of secondary dentine.

The fact that the tubuli are capable of being injected by a material external to the tooth has suggested the experiment of attempting to obtain the same result with a material more suitable for the purpose.

With this object in view, I have placed a layer of chloride of lime beneath the stopping, choosing only cases of extensive softened dentine; but I have been recently making the attempt with a solution of silica, by reducing it to a gelatinous condition, and in that state inserting it beneath the plug. The results of these experiments are yet in the future, but I am strongly persuaded that the treatment is good, and will lead to satisfactory results.

ILLUSTRATIONS.

18. Same, one-fifth do.
19. Section of a tooth, showing nodular dentine in the midst of secondary dentine (seen by transmitted light).
20. Second specimen from the same tooth (seen by opaque light).
21. Molar tooth, showing the membrane between the dentine and enamel (dissected out).
22. Shows structure of the same.
23. Section of decayed tooth, showing the defined boundary of the disease to be parallel with the direction of the tubuli.
24. Sections of decayed enamel, showing the tendency of its decomposition to proceed more rapidly from the base outwards than from without inwards.
25. Section of a tooth, showing the same as last, from a specimen that had been plugged with gold seventeen years. *a a*, line of limit to disease.
26. Section of a block of walrus dentine, that had been in the mouth eighteen months: *a*, showing the transparent margin, anticipating caries.
27. Section of caries, showing the increased diameter of the dentinal tubuli.
28. Same, more highly magnified.
29. Section of normal dentine from same tooth as two last.
30. Transverse section of caries, showing the spaces from which the tubuli have been removed.
31. Section of caries, showing the obliteration of the tubuli and the increased visibility of the areolar structure of the dentine.
32. A tooth with an abscess in the dentine. *b, c*, two surfaces of the bisected fang.

Fig 1.

PL. 1.

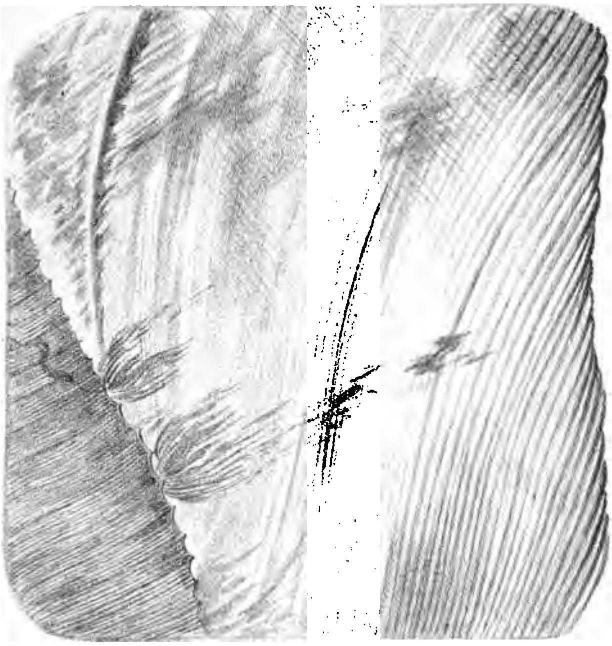
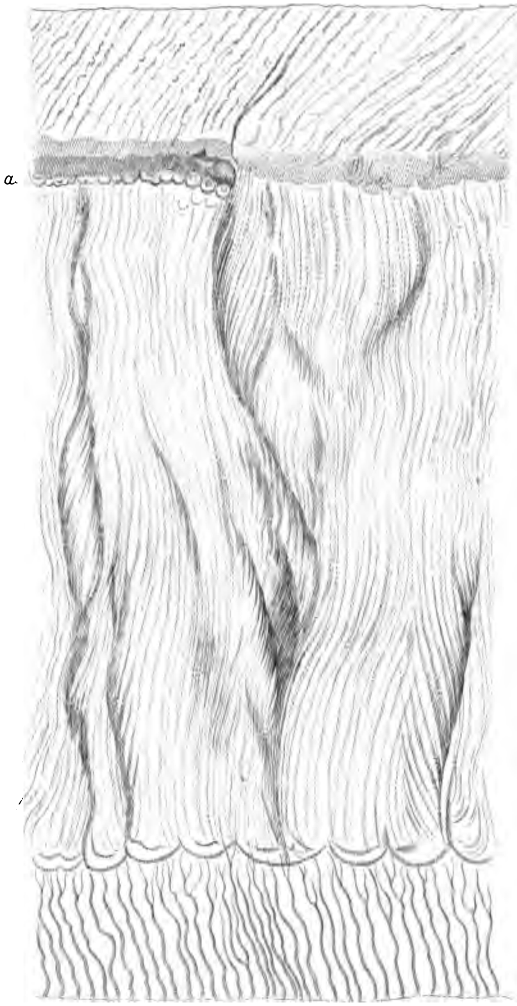


Fig 2

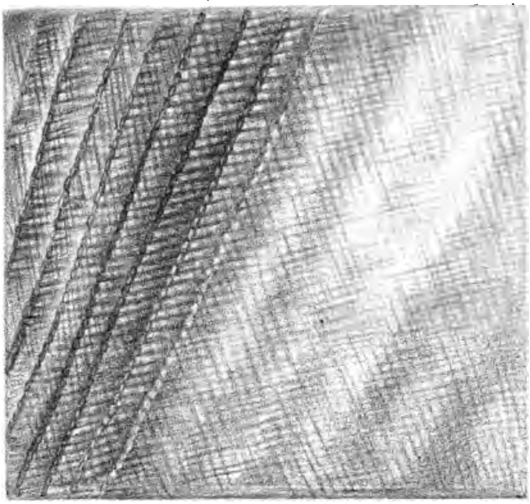
Fig 3

Pl II



W Bagg Sculp

Fig. 4



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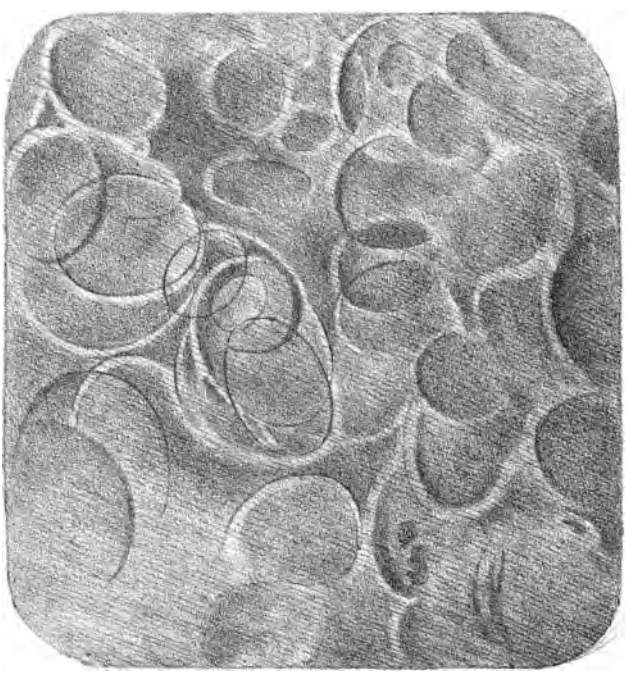


Fig 5 PL. 4

Fig. 6.

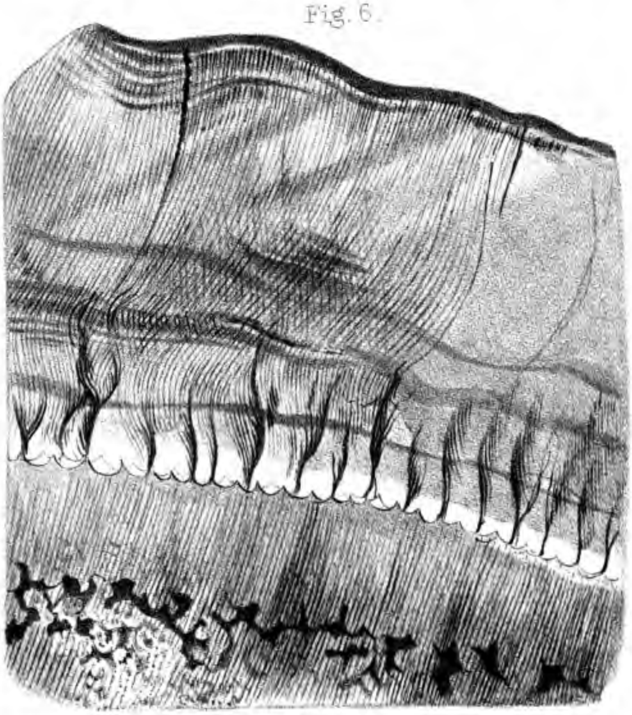
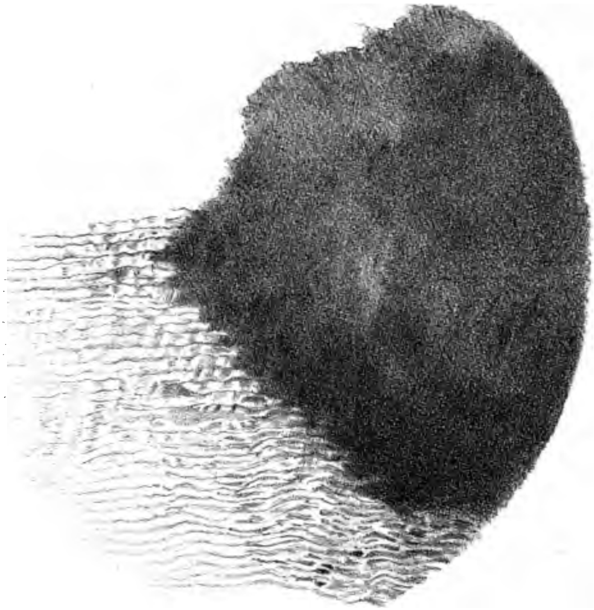
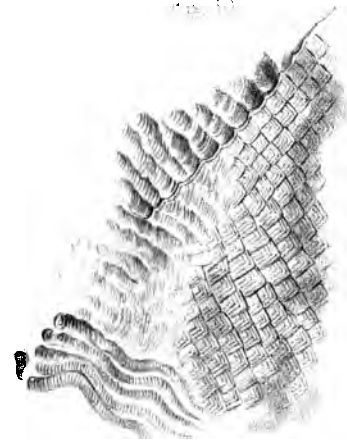


Fig 11.





Fig

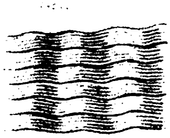
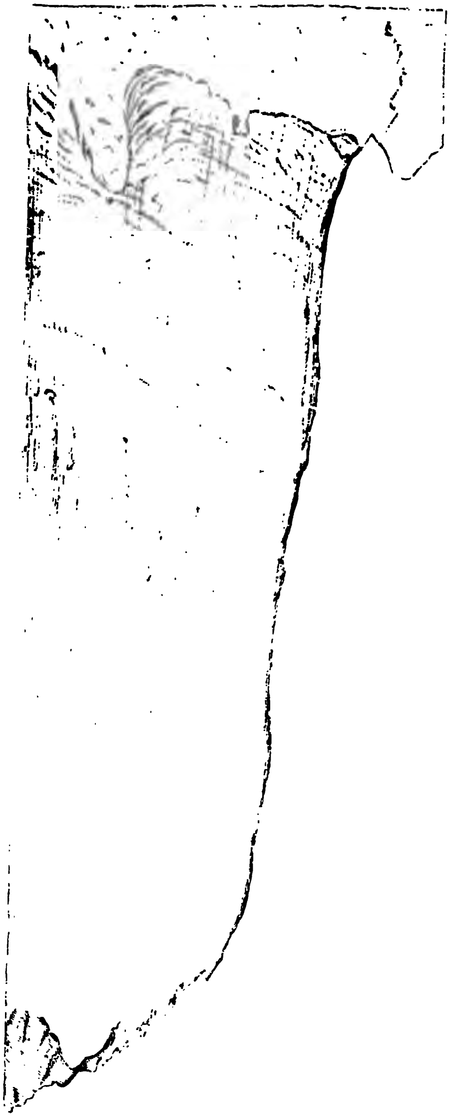


Fig 12

Pl VI



N. Bogg Sculp

Fig 13

Pl VII

W. Bagg Sculp

Fig. 14

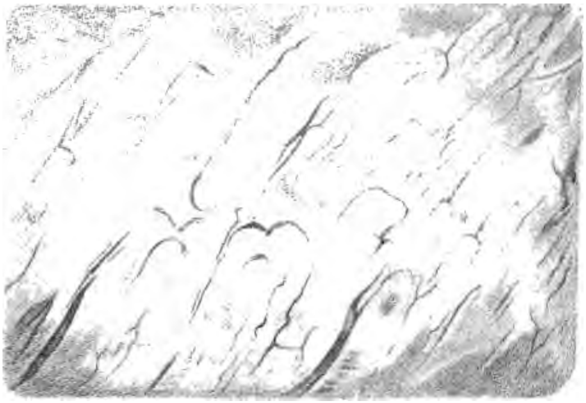


Fig. 16.

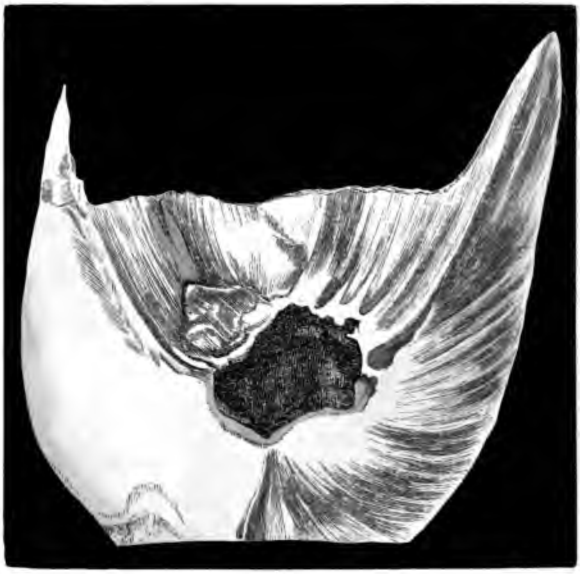


Fig. 17

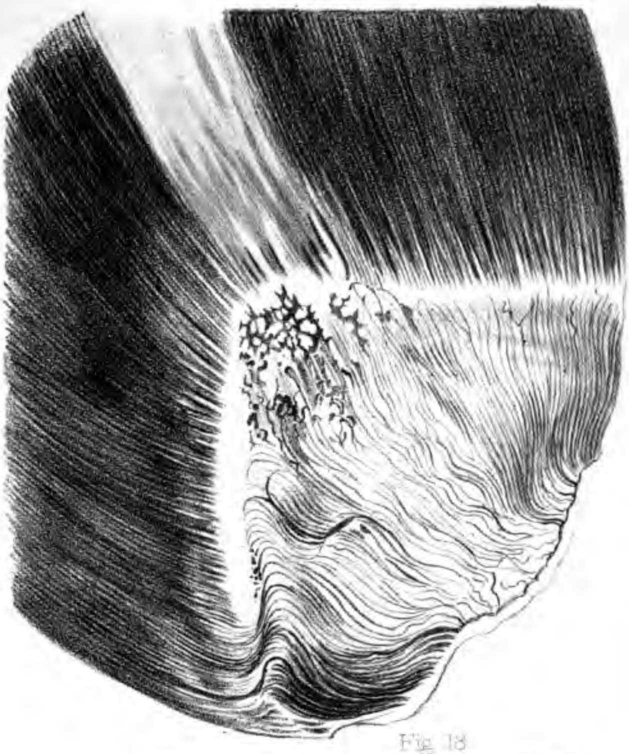
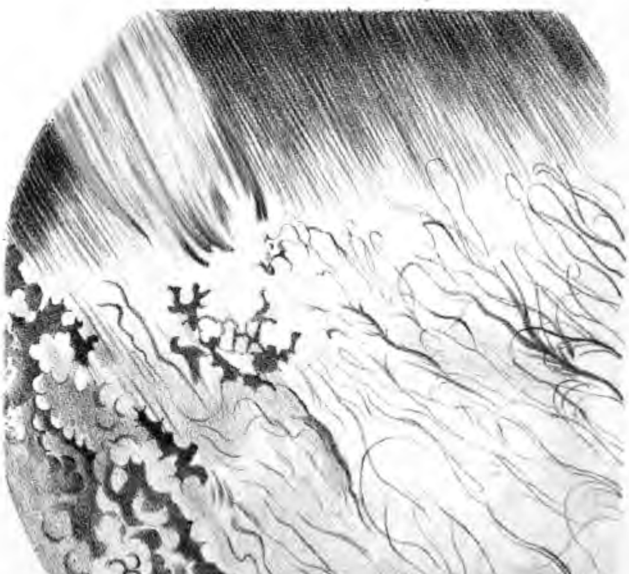


Fig. 18



Pl.

Fig. 19

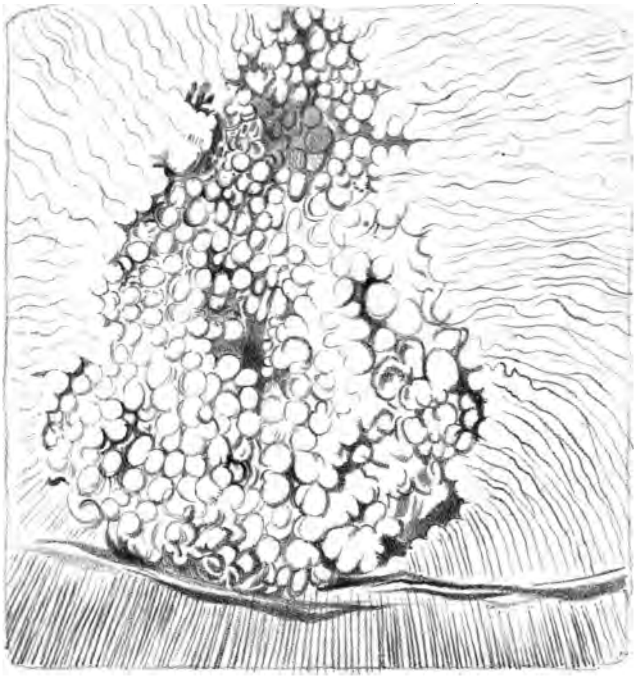


Fig. 20

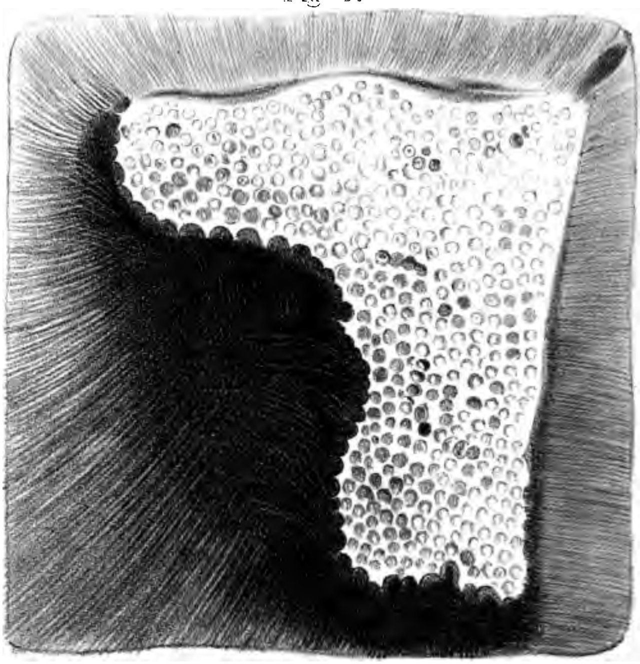


FIG. 23.

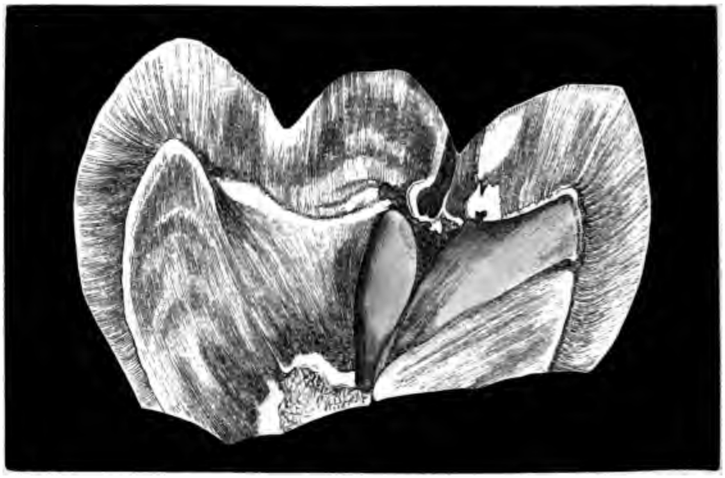


FIG. 25.

Fig. 24.

Fig. 27

Fig. 28.

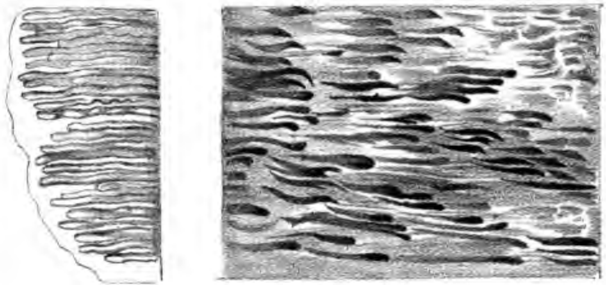


Fig. 29

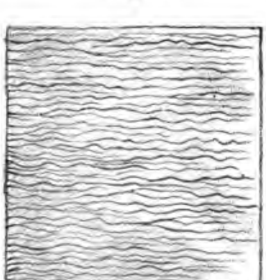


Fig. 30